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An Interservice Comparison of Recruiting Efficiency Using Data Envelopment Analysis

by

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Submitted in partial fulfillment of the
requirements for the degree of

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ABSTRACT

As budget and force reductions continue, Navy recruiting must become more efficient, using fewer dollars and resources. In an effort toward achieving this goal, this thesis proposes two procedures to evaluate the efficiency of Navy recruiting. Both procedures are based on two Data Envelopment analysis models. One procedure assumes that all inputs are discretionary and the other does not. To demonstrate their effectiveness, the two procedures were implemented in the General Algebraic Modeling System (GAMS) and used to analyze the efficiency of recruiting districts from the four services: Navy, Marine Corps, Army and Air Force.

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I. INTRODUCTION

Budget downsizing will continue to force reductions in the total number of personnel serving in the United Sates Navy. As a result, fewer billets will need to be filled. It might seem that this would make recruiting easier. In reality, maintaining an adequate (all volunteer) national defense will require that remaining billets be filled by the best qualified young people. Attracting these higher quality enlistees demands that recruiting efforts be ever more concentrated on a smaller eligible pool. Furthermore, the ability of the Navy to effectively compete in the recruiting market is under increasing challenge from the other Services and private industry. To meet this challenge, Navy recruiting must be efficient as well as effective.

A. BACKGROUND

Commander Navy Recruiting Command (CNRC), headquartered in Arlington, Virginia, was responsible for recruiting over 130,000 individuals in 1991. Accomplishing this required a budget of some 400 million dollars and a "sales force" of more than 4000 recruiters. These salespeople are distributed throughout the geographic United States, which is divided into five recruiting areas, and further subdivided into 41 districts. Districts are split into 287

zones, and the zones are split into 1283 stations. Stations then provide face to face sales effort for United States Navy recruiting.

This thesis focuses on measuring the efficiency of recruiting efforts at the district level. Of particular interest is the comparison of Navy efforts with those of the Marine Corps, Army, and Air Force. Unlike production entities in industry, recruiting efficiency is not readily quantified using traditional concepts such as prices and production functions. First, recruiting districts are by nature not-for-profit organizations. Second, the "products" or "outputs" of recruiting districts are the numbers of each "quality category" of young people who enlist. So it is difficult, and subjective at best, to associate a monetary value with each recruit category in order to compare district efficiencies on the same (absolute) scale. In order to avoid entirely the issue of setting an absolute scale, this thesis employs Data Envelopment Analysis (DEA), originally proposed by Charnes, Cooper and Rhodes (1978).

B. ORGANIZATION

Chapter II provides background on DEA. Specifically, two DEA models are examined. The first assumes that resources used in recruiting are discretionary, the second model treats some resources as non-discretionary. Chapter III uses each of the two models to analyze and compare Navy recruiting efforts to those of the Marine Corps, Army, and Air Force. Finally,

Chapter IV summarizes the thesis and provides suggestions for future investigation.

II. DATA ENVELOPMENT ANALYSIS (DEA)

Charnes, Cooper, and Rhodes (1978) proposed Data Envelopment Analysis (DEA) as a method with which to evaluate the efficiency of Decision Making Units (DMUs). Their term DMU emphasizes the not-for-profit nature of the entities under consideration. The concept of efficiency used in DEA is based on the ratio of outputs to inputs for a given DMU. Outputs refer to the products, benefits or outcomes created by a given DMU. Inputs are simply the resources used in creating these outputs. In some cases, inputs are further segregated into two categories. One category encompasses inputs which can be controlled by a DMU and are referred to in the literature as "discretionary". The other category of inputs is referred to as "non-discretionary", since their levels are beyond the decision maker's control.

The idea of efficiency as a ratio of outputs to inputs has intuitive appeal. A greater ratio represents more output per input, i.e., higher efficiency. This natural appeal has motivated researchers to study and extend DEA models in various directions. Of particular interest here is the work of Banker and Morey (1986) who extended the basic DEA model, to allow for the discrimination between discretionary and non-discretionary inputs. Other applications of DEA to evaluate organizational efficiency include hospital production (Banker, et al., 1986), Electric Cooperatives (Thomas, 1986), U.S. Air Force Equipment

Maintenance (Charnes, et al., 1985), U.S. Army Recruiting (Charnes 1990), Program Follow Through (Charnes, et al., 1981), School efficiency (Bessent, et al., 1980) and others. These are only a few examples. A comprehensive bibliography (Seiford 1990) listed over 400 publications related to DEA.

The next sections address two basic DEA models. The first assumes that all inputs are discretionary, the second that some inputs are beyond the DMU's control. Each section begins by describing a DEA model as it appears in the literature. However, when the models are applied to the measurement of organizational efficiency, there are some inconsistencies. To overcome them, alternative procedures are proposed.

A. MODEL WITH ALL INPUTS DISCRETIONARY

To begin, define the following

Indices:

d index of DMU where d = 1,...,n and n = total number of DMUs

i index of inputs where i = 1,...,r and r = the number of (different) inputs

j index of outputs where j = 1,...,p and p = the number of (different) outputs

Problem data:

x_{id} amount of input i used by DMU d

y_{jd} amount of output j produced by DMU d

Using the above notation, DEA defines efficiency based on a ratio of weighted outputs to inputs in the following manner:

$$Z_d = \frac{\sum_{j=1}^{p} u_j y_{jd}}{\sum_{i=1}^{r} v_i x_{id}}$$

where

u_j = weight assigned to output j

v_i = weight assigned to input i

Z_d = the ratio of outputs to inputs for DMU d

Note that weights u_j and v_i together can be thought of as factors which convert outputs and inputs of different types (and scales) to one universal measure. In DEA methodology, each DMU is allowed to choose its own weights. If all DMUs were required to use the same weights in calculating their ratios, it would in effect be like assigning values (e.g., costs or prices) to each input and output. But assignment of costs/prices is inappropriate, particularly to outputs, in the not-for-profit setting. Weights u_j and v_i are not, however, chosen arbitrarily. In particular, they must satisfy the following criteria:

1) All weights must be positive, i.e., $u_j > 0$ and $v_i > 0$ for all i and j.

2) No DMU's ratio is allowed to exceed a value of one using a given set of weights.

Thus, to determine how efficient a given DMU is, DEA selects that set of weights which maximize the DMU's ratio, while satisfying both criteria. More

specifically, the problem of determining efficiency for DMU k can be formulated as follows:

[DEA1]:

$$Z_k = maximize \; \frac{\sum_{j=1}^{p} u_j y_{jk}}{\sum_{i=1}^{r} v_i x_{ik}}$$

subject to:

$$\frac{\sum_{j=1}^{p} u_j y_{jd}}{\sum_{i=1}^{r} v_i x_{id}} \leq 1 \qquad for\ d = 1,\ldots,n$$

$$u_j > 0 \qquad for\ j = 1,\ldots,r$$

$$v_i > 0 \qquad for\ i = 1,\ldots,p$$

Note, the first constraint ensures that criterion two is satisfied, and can be equivalently written as

$$\sum_{j=1}^{p} u_j y_{jd} \leq \sum_{i=1}^{r} v_i x_{id} \qquad for\ d = 1,\ldots,n.$$

This makes the constraint linear. The objective function, however, is still nonlinear and can be shown to be both pseudo-convex and pseudo-concave (see, e.g., Bazaraa and Shetty, 1979).

If the solution to the optimization problem, DEA1, yields a ratio of one, i.e., $Z_k = 1$, then DMU k is considered to be efficient. If $Z_k < 1$, then DMU k is inefficient and Z_k represents an "efficiency ratio". However, there are no optimization procedures that can effectively handle the last two sets of constraints in DEA1. To apply existing procedures to DEA1, the strict inequalities must be relaxed, thereby allowing the weights to be zero. However, zero weights do not provide answers consistent with the definition of efficiency.

To illustrate, consider an example with six DMU's. Each uses one unit of input to produce two types of output. The data for these notional DMUs is displayed in Table 1.

TABLE 1: AN EXAMPLE PROBLEM

DMU	INPUT	OUTPUT 1	OUTPUT 2
1	1	7	2
2	1	6	4
3	1	4	5
4	1	3	5
5	1	3	4
6	1	0	4

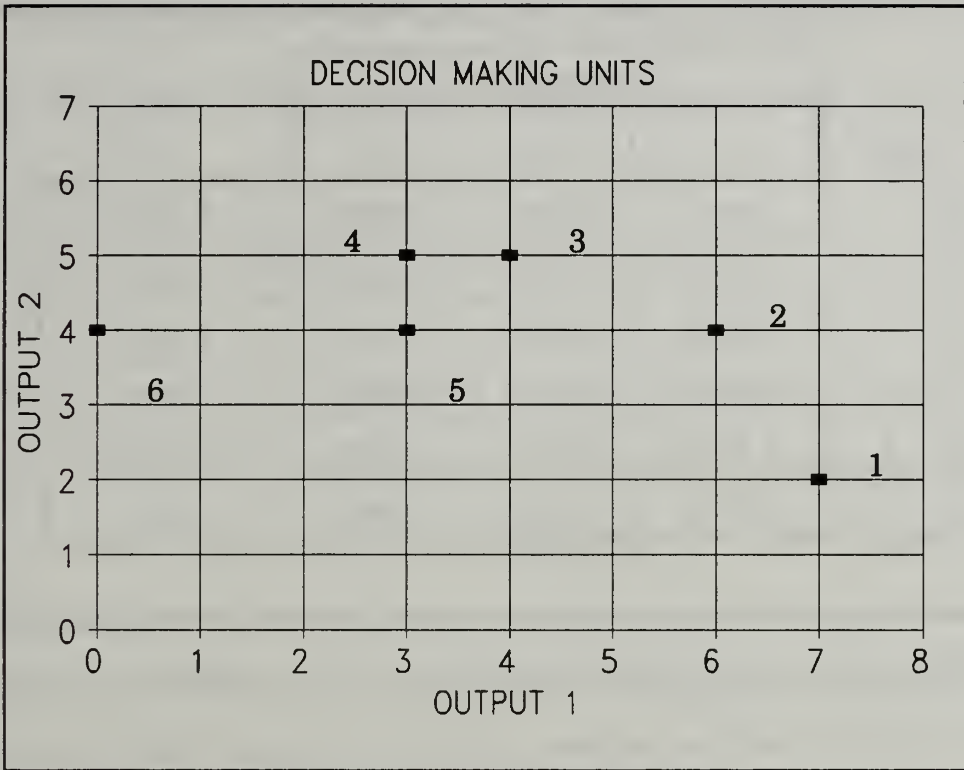

FIGURE 1: Data from the Example Problem

Figure 1 graphically displays the data in Table 1. Note that only output amounts are plotted, since each DMU uses a single unit of input. Applying problem DEA1 (with zero weights allowed) to the above data yields the following ratios: $Z_1 = Z_2 = Z_3 = Z_4 = 1.0$, and $Z_5 = Z_6 = 0.8$. (Table 2 provides the complete results.)

TABLE 2: DEA1 SOLUTION TO THE EXAMPLE PROBLEM

DMU	WEIGHTS v_1	WEIGHTS u_1	WEIGHTS u_2	Z
1	1.0000	0.1336	0.0324	1.0000
2	1.0000	0.1250	0.0625	1.0000
3	1.0000	0.0714	0.1429	1.0000
4	1.0000	0.0000	0.2000	1.0000
5	1.0000	0.0000	0.2000	0.8000
6	1.0000	0.0000	0.2000	0.8000

Unfortunately, these results suggest that DMU 4 is efficient. Compared to DMU 3, DMU 4 produces one fewer units of output one. Clearly then, DMU 4 is not efficient. This incorrect efficiency ratio is due to the fact that in order to achieve a ratio equal to 1.0 for DMU 4, u_1 is set to zero, u_2 to 0.2 and v_1 to 1. Then,

$$Z_4 = \frac{0 \cdot 3 + 0.2 \cdot 5}{1} = 1.0$$

To reveal another inaccuracy, compare Z_5 and Z_6. DMU 5 produces 3 and 4 units of outputs one and two, respectively, while DMU 6 produces 4 units of output two and none of output one. Intuitively, we expect that DMU 6 is substantially less efficient than DMU 5. However, DEA1 yields values for Z_5 and Z_6 which indicate they have the same efficiency.

In order to overcome the deficiency of allowing weights to be zero, Charnes and Cooper (1985) replaced the last two sets of constraints in DEA1 with

$$u_j \geq \epsilon \qquad \text{and} \qquad v_i \geq \epsilon$$

where ϵ is a small, (non-archimedian) constant, generally set to 10^{-6} in the literature. While this constant solves the problem of identifying efficient DMUs, it causes the ratio, Z_d, for inefficient DMUs to be unusable as an efficiency rating when some weights assume the value of ϵ. That is, $u_j = \epsilon$ for some j and/or $v_j = \epsilon$ for some i. In particular, under this ϵ-modification,

$$Z_4 = \frac{3\epsilon + (1/5 - \epsilon)5}{1} = 1 - 2\epsilon$$

$$Z_5 = \frac{3\epsilon + (1/5 - \epsilon)4}{1} = 0.8 - \epsilon$$

$$Z_6 = \frac{(1/5 - \epsilon)4}{1} = 0.8 - 4\epsilon$$

As before, these numbers do not reflect the true efficiency for the corresponding DMUs. For small values of ϵ, Z_4 is almost 1, indicating that DMU 4 is close to being efficient. Similarly, Z_5 and Z_6 are approximately the same when ϵ is small. So, DMUs 5 and 6 have approximately the same efficiency. These conclusions are similar to those obtained when zero weights are allowed. As in the efficient DMU cases, these efficiency ratio values are inaccurate when ϵ is set to 10^{-6}. To ensure that the ratios are accurate for

nonefficient DMUs, we propose the following alternative procedure for computing an efficiency rating.

<u>An Alternative Procedure</u>

Step 1: For each DMU k, solve problem DEA1 with $u_j \geq 0$ and $v_i \geq 0$. Denote $(u_1^k, \ldots, u_p^k, v_1^k, \ldots, v_r^k)$ as the optimal set of weights for DMU k.

Step 2: Discard all weight sets in which some of the weights are zero. Let L be a set of indices of the remaining sets of weights, i.e.,

$$L = \{k : u_j^k > 0 \text{ and } v_i^k > 0 \text{ for all } i \text{ and } j\}$$

Step 3: Recalculate ratios for all DMUs as follows:

$$Z_d = \max \left\{ \frac{\sum_{j=1}^{p} u_j^k Y_{jd}}{\sum_{i=1}^{r} v_i^k x_{id}} : k \in L \right\}$$

Table 3 displays the efficiency ratings for the example problem. Note that they conform more closely to intuition. In particular, the efficiency rating for DMU 5 now reflects the fact that it is more efficient than DMU 6.

Figure 2 shows the efficient frontier based on the alternative procedure. Using this frontier, the efficiency ratings in Table 3 can be graphically calculated as in Charnes, Cooper, and Rhodes (1978) and Charnes and Cooper (1985). To illustrate, the efficiency ratio for DMU 4 is simply the ratio of the

TABLE 3: SOLUTION USING THE ALTERNATIVE PROCEDURE

DMU	WEIGHTS			Z
	v_1	u_1	u_2	
1	1.0000	0.1336	0.0324	1.0000
2	1.0000	0.1250	0.0625	1.0000
3	1.0000	0.0714	0.1429	1.0000
4	1.0000	0.0714	0.1429	0.9286
5	1.0000	0.0714	0.1429	0.7857
6	1.0000	0.0714	0.1429	0.5714

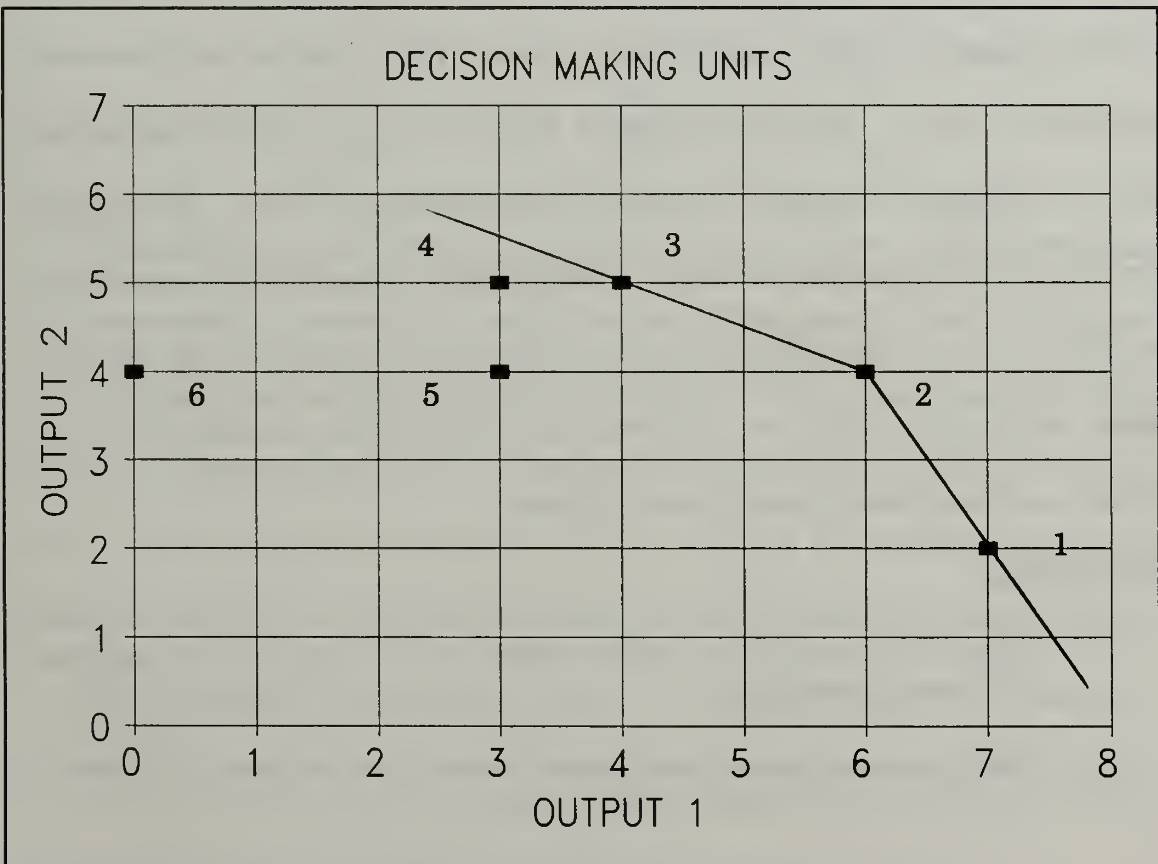

FIGURE 2: Graph of 6 DMU Example with Adjusted Frontier

length of the line segment from the origin to DMU 4 and the length of the line segment from the origin to the efficiency frontier passing through DMU 4, i.e.,

$$Z_4 = \frac{\sqrt{3.0^2 + 5.0^2}}{\sqrt{3.4^2 + 5.3^2}} \approx 0.925.$$

B. MODEL WITH MIXED INPUTS

In practice, many inputs may be critical to a DMU but beyond a decision maker's control. In the literature, these inputs are referred to as non-discretionary inputs. At a recruiting district, these non-discretionary inputs typically include the unemployment rate, the populations of 17-21 year-olds, and propensity to enlist. Neglecting to discriminate between discretionary and non-discretionary inputs may leave valuable DEA results undiscovered. Specifically, DEA can provide information about how a DMU should adjust the level of its inputs or outputs in order to become more efficient. By treating discretionary and non-discretionary inputs similarly, as in DEA1, it is implicitly assumed that non-discretionary input levels can be varied by the decision maker, which is not the case. Banker and Morey (1986) modified DEA1 to handle non-discretionary variables as follows:

New indices:

- *i* index for discretionary inputs where i = 1,...,r and r = the number of discretionary inputs,
- *f* index for non-discretionary inputs where f = 1,...,q and q = the number of non-discretionary inputs.

To evaluate DMU k, one solves the following optimization problem:

[DEA2]:

$$W_k = maximize \frac{\sum_{j=1}^{p} u_j y_{jk} - \sum_{f=1}^{q} v_f x_{fk}}{\sum_{i=1}^{r} v_i x_{ik}}$$

subject to

$$\frac{\sum_{i=1}^{p} u_j y_{id} - \sum_{f=1}^{q} v_f x_{fd}}{\sum_{i=1}^{r} v_i x_{id}} \leq 1 \qquad for\ d=1,\ldots,n$$

$$u_j > 0 \qquad for\ j = 1,\ldots,p$$

$$v_i > 0 \qquad for\ i = 1,\ldots,r$$

$$v_f \geq 0 \qquad for\ f = 1,\ldots,q$$

DEA2 differs from DEA1 in two important ways. First, v_f is required only to be nonnegative. Second, the weighted sum of the non-discretionary inputs is subtracted from the weighted sum of outputs in the numerator. In effect, this cancels that portion of the outputs which was caused by non-discretionary inputs. The remaining outputs must be the result of discretionary inputs. Hence, the ratio now represents controllable outputs over controllable inputs.

The problem with requiring u_j and v_i to be positive still exists, just as it did in DEA1. It can be solved here in a similar fashion, involving only a change

in Step 3 of the alternative procedure. For the case involving mixed inputs then, Step 3 should read as follows:

Step 3: Recalculate the ratios for all DMUs as follows:

$$W_d = \text{maximize} \left\{ \frac{\sum_{j=1}^{p} u_j^k Y_{jd} - \sum_{f=1}^{q} v_f^k x_{fd}}{\sum_{i=1}^{r} v_i^k x_{id}} : k \in L \right\}.$$

Then, using the results from both alternative procedures, one from DEA1 and the other from DEA2, the efficiency ratio for DMU d with mixed inputs is the maximum of Z_d and W_d.

III. IMPLEMENTATION AND RESULTS

To evaluate the efficiency of Navy recruiting districts, DEA1, DEA2 and the corresponding alternative procedures were implemented in GAMs, a mathematical solver of optimization models (see, Brooke et al., 1988). For this study, Navy recruiting districts were considered DMUs. Inputs for these districts consist of the number of recruiters, the unemployment rate and population size for the district, and outputs consist of the number of recruits (contracts) enlisted in categories 1-3A and 3B. Navy Recruiting Command extracted the necessary data from the Defense Manpower Data Center (DMDC) database for the years 1987 to 1990. The corresponding data for the Marine Corps, Army and Air Force are based on the geography of Navy recruiting districts.

A. RESULTS WITH DISCRETIONARY INPUTS

To provide a basis for later comparison, the non-discretionary inputs, i.e., unemployment rate and population size, are not considered in this section. Table 4 displays the number of contracts per recruiter in each district for 1987. These data are depicted graphically in Figure 3. Solving problem DEA1 with 1987 data and only requiring the weights to be nonnegative yields no usable efficiency ratios because the model produced at least one zero weight for every

TABLE 4: NUMBER OF CONTRACTS PER RECRUITER IN 1987

	NAVY		MARINES		ARMY		AIR FORCE	
D	A	B	A	B	A	B	A	B
1	11.2763	4.6379	14.6395	3.7327	10.1652	3.3124	13.4927	7.9989
2	9.7288	4.7256	12.9208	3.2946	10.6701	3.0828	15.5892	10.1638
3	15.2676	5.9550	17.7942	4.1359	15.1648	4.6492	16.0468	8.2573
4	10.8101	8.2278	6.8201	1.9382	11.1746	6.5891	19.1325	17.4699
5	16.0215	5.3405	16.6494	4.1002	12.0000	4.9636	15.6482	6.5962
6	11.0070	6.4356	10.9692	2.6462	9.1306	4.6556	15.2207	9.4474
7	12.9679	6.2855	18.4298	5.6129	12.7781	6.3759	16.9441	8.1096
8	9.5099	5.7465	8.8695	2.5418	8.8337	4.2954	13.9755	9.6942
9	14.5268	6.6633	12.3620	3.0215	11.1886	6.0646	18.0680	11.3741
10	13.3333	9.8480	16.1329	5.8952	16.2619	11.7678	18.6153	10.8207
11	13.4825	11.2303	14.6410	5.6585	14.9177	12.0615	20.5827	11.3722
12	15.4297	6.1719	21.5076	5.2238	18.9187	8.1135	31.5026	14.1278
13	15.3199	11.4175	11.7588	4.0478	16.6981	11.1164	20.2283	10.6651
14	13.8317	7.4515	13.8235	5.0737	16.1471	6.7156	20.2863	10.9202
15	13.4921	9.5447	14.3688	5.7535	14.0432	10.2258	19.0325	11.1143
16	11.9197	6.6493	13.7232	3.3483	15.2384	8.9502	20.7992	6.25
17	14.8608	6.9050	16.5236	5.5877	17.7125	8.5924	18.5100	12.9032
18	15.5725	6.3225	7.9376	1.5775	12.3300	4.8596	10.1183	6.6272
19	19.0360	9.3712	16.8285	4.5378	14.8794	7.6455	18.3457	8.8642
20	16.3006	8.2007	16.7567	5.0855	14.5785	7.0083	15.0716	9.7749
21	14.5100	8.6530	12.0946	2.9706	12.4843	6.5801	23.1010	13.6282
22	17.1062	8.5420	13.0105	3.5056	14.0701	6.1388	19.7913	10.9727
23	18.8269	5.7711	16.6608	3.7921	12.2227	3.5965	17.0936	8.3116
24	22.9743	7.2655	19.1440	4.2027	14.0466	4.6915	21.6904	8.6303
25	14.6116	6.3967	19.6106	4.6824	14.4627	5.7406	14.4527	8.4949
26	17.7822	6.0651	15.6772	2.7973	13.8799	3.6770	20.6623	10.7623
27	14.4817	6.4817	16.0101	4.7163	15.0742	7.0031	20.6179	11.4146
28	21.2169	7.9191	17.2316	4.0892	16.9044	5.2931	21.2273	8.9927
29	18.8588	7.8090	13.3950	2.9886	16.7025	5.9973	20.9800	9.5623
30	21.9089	10.9545	20.2950	5.6815	17.0399	8.4266	19.9607	9.0954
31	19.2031	8.5454	15.4520	4.321	17.8593	7.9899	27.5779	11.1111
32	19.6972	10.9641	14.9373	4.2621	18.4468	8.6277	37.7904	18.7535
33	17.3518	8.7127	21.1646	7.0204	17.2375	9.3737	19.7755	11.0681
34	19.5787	11.7048	15.3887	5.464	18.2074	13.3636	32.4838	12.9750
35	18.9019	10.0631	24.2121	6.6615	16.6511	8.6522	28.1521	10.2502
36	12.8886	12.4914	13.7288	6.3347	12.6548	11.9490	13.0711	10.6599
37	15.1734	10.0148	8.1009	1.9662	13.4058	5.6087	16.3483	10.4608
38	19.5164	7.1052	14.1891	3.3819	17.7738	4.9194	24.6903	9.7378
39	16.0267	8.9549	11.3292	3.1271	12.5146	4.9928	16.4484	8.6803
40	22.1787	6.2824	14.8571	3.0037	16.7374	4.3578	20.2972	9.8169
41	15.7737	7.0511	13.4215	2.7615	18.0214	5.8546	28.4775	14.8138

D = district

A = (no. of 1-3A contracts) ÷ (no. of recruiters)
B = (no. of 3B contracts) ÷ (no. of recruiters)

district. This is also evident in Figure 3 which suggests that Air Force district 32 is the only efficient district among a total of 164 districts. To make the results from DEA1 more meaningful, Air Force district 32 is treated as "super

efficient" and is removed from the model. Without Air Force district 32, the alternative procedure produced the efficiency ratings in Table 5. Note that the efficiency rating for Air Force district 32 is larger than one to indicate its status as being super efficient. Based on these efficiency ratings, Figure 4 shows the corresponding efficiency frontier which is completely defined by Air Force districts. Being super efficient, Air Force district 32 lies above the frontier. To compare Navy recruiting efforts against those of the Air Force, data points for Army and Marine Corps districts are removed in Figure 5.

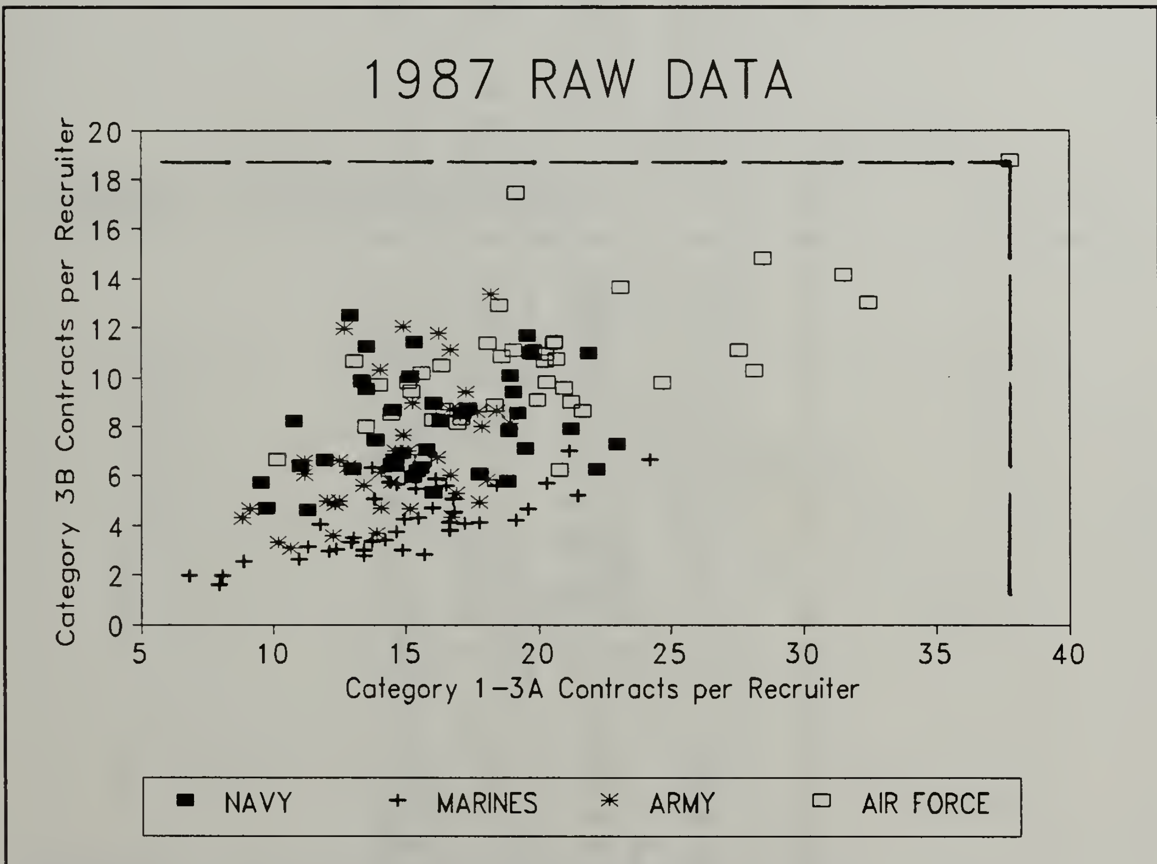

FIGURE 3: Number of Contracts per Recruiter in 1987

Data from 1988 through 1990 were analyzed in a similar manner and the results are summarized in Figure 6. From this figure, it is clear that Air Force districts dominate those from the other services in the first three years. In 1990, Navy districts are slightly more efficient than Air Force districts on average.

TABLE 5: 1987 EFFICIENCY RATINGS

DISTRICT	NAVY	MARINES	ARMY	AIR FORCE
1	0.3498	0.4093	0.2983	0.5143
2	0.3248	0.3613	0.3054	0.635
3	0.4672	0.4897	0.4393	0.5562
4	0.4924	0.1946	0.4244	1.0
5	0.4725	0.4627	0.3727	0.4885
6	0.4156	0.3038	0.3146	0.5989
7	0.4324	0.5332	0.4341	0.5604
8	0.3673	0.2535	0.2952	0.595
9	0.4677	0.3431	0.4014	0.718
10	0.5941	0.4859	0.7139	0.7001
11	0.657	0.447	0.7108	0.748
12	0.4752	0.5963	0.5933	1.0
13	0.6872	0.3493	0.6903	0.7125
14	0.4942	0.4168	0.5023	0.7245
15	0.5826	0.4426	0.6193	0.7181
16	0.436	0.3808	0.5772	0.6001
17	0.4824	0.4889	0.5909	0.7909
18	0.4814	0.2132	0.3783	0.4135
19	0.6411	0.4754	0.5153	0.6105
20	0.5568	0.4844	0.4835	0.6116
21	0.5554	0.336	0.4396	0.8777
22	0.5815	0.3675	0.4433	0.7209
23	0.5454	0.4569	0.3511	0.5711
24	0.6699	0.522	0.4144	0.6671
25	0.4608	0.5421	0.4445	0.5477
26	0.5271	0.4149	0.3908	0.722
27	0.4594	0.46	0.4892	0.7503
28	0.6423	0.4758	0.4919	0.6635
29	0.586	0.3662	0.501	0.6728
30	0.7453	0.5774	0.5756	0.64
31	0.6083	0.4395	0.5665	0.8508
32	0.7194	0.4265	0.6012	1.2794
33	0.5919	0.6235	0.6198	0.7249
34	0.7507	0.4604	0.8076	1.0
35	0.6701	0.6865	0.5809	0.8472
36	0.7056	0.4437	0.6788	0.6269
37	0.6234	0.2246	0.4177	0.6572
38	0.5873	0.3921	0.5045	0.7577
39	0.5868	0.3214	0.3851	0.5797
40	0.6324	0.4001	0.4697	0.6759
41	0.5003	0.3623	0.5285	0.9942
AVERAGE	0.5519	0.4251	0.4966	0.7103

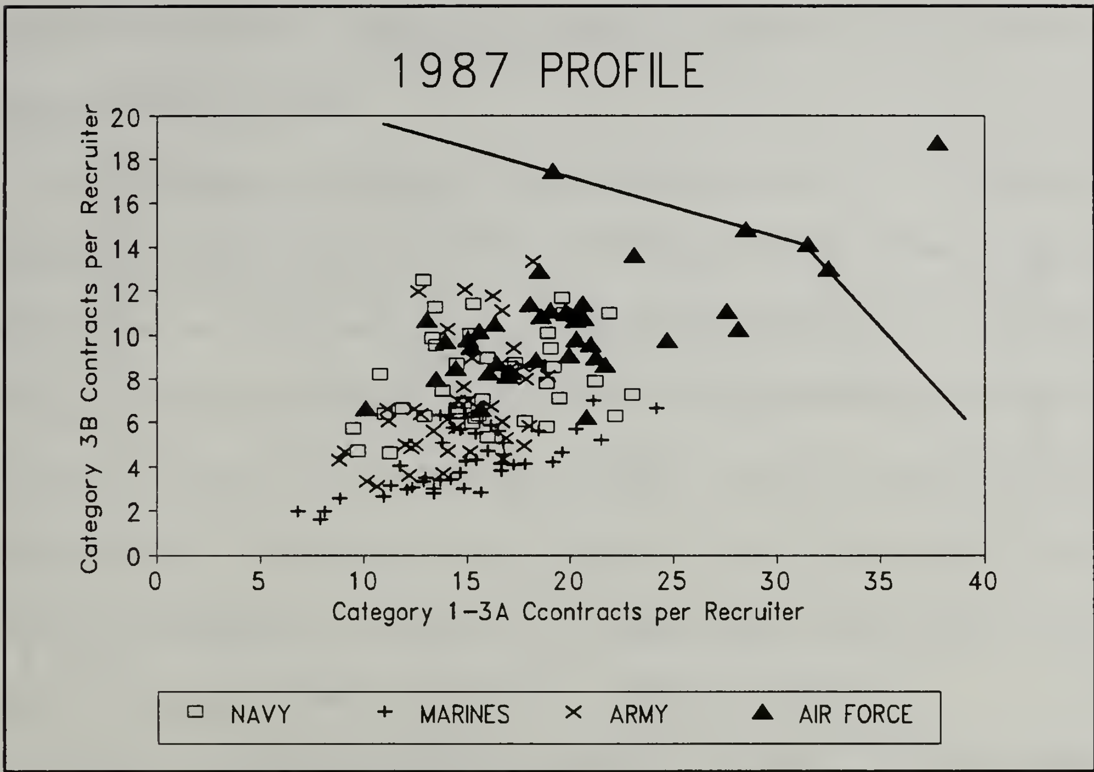

FIGURE 4: 1987 Efficiency Frontier

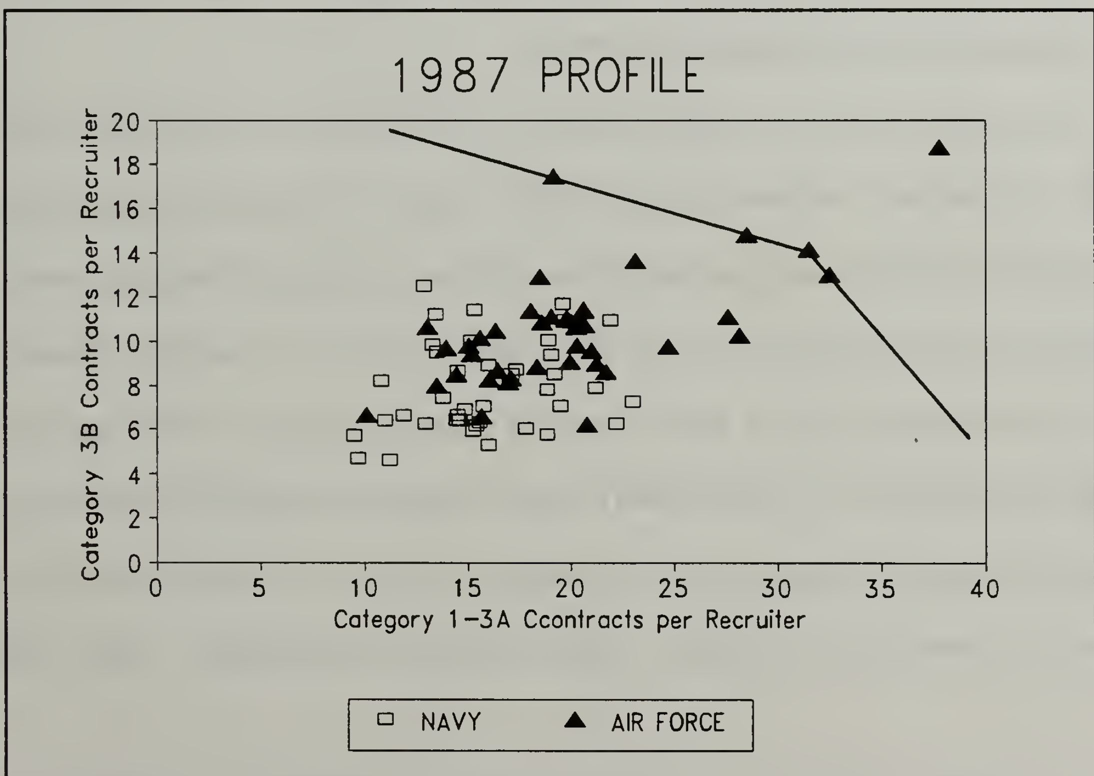

FIGURE 5: 1987 Efficiency Frontier for Navy and Air Force Districts

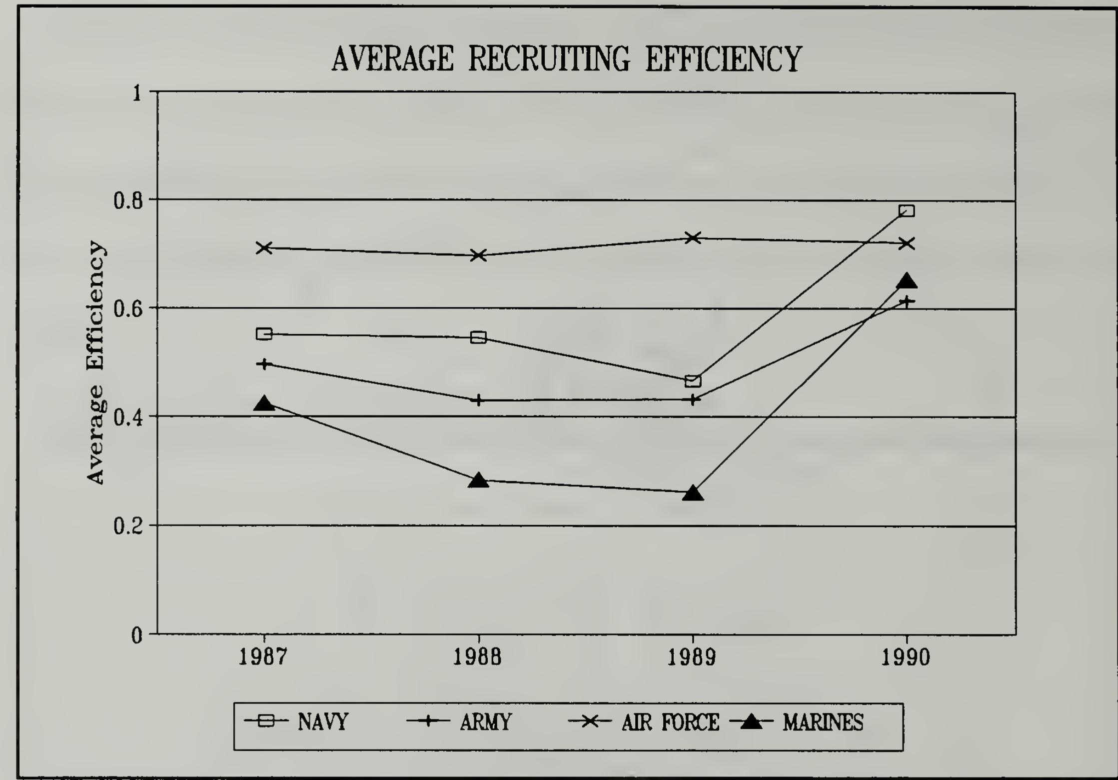

FIGURE 6: Average Recruiting Efficiency Based on DEA1

B. RESULTS WITH MIXED INPUTS

In addition to the non-discretionary inputs listed above, the models used in this section also include the propensity to enlist. Values of propensity to enlist for each service were extracted from the Youth Attitude Tracking Survey (YATS) and are assumed to be constant over all districts. In the first attempt, all non-discretionary inputs were treated as discretionary and DEA1 was used to compute efficiency. This provided no usable efficiency ratings because DEA1 again produced zero weights for every district. Moreover, the additional inputs make the identification of super efficient districts impossible. Thus, this

approach was abandoned. Below, we provide the results from the alternative procedure based on DEA2.

Table 6, Figure 7 and Figure 8 summarize the results for 1987 using the alternative procedure based on DEA2. Note that the new efficiency ratings indicate that on the average Navy and Air Force districts have comparable efficiency. In particular, Figure 7 shows that more districts from services other than the Air Force lie on the efficiency frontier. Figure 9 compares average efficiency ratings over the four years. Note that the Navy, Army and Air Force districts are comparable, perhaps with the Navy having a slight edge over the other two services.

TABLE 6: 1987 ADJUSTED EFFICIENCY

DISTRICT	NAVY	MARINES	ARMY	AIR FORCE
1	0.4925	0.5205	0.4775	0.5143
2	0.5187	0.596	0.5589	0.8259
3	0.7042	0.6849	0.7023	0.5562
4	0.7111	0.1946	0.6295	1.0
5	0.7178	0.615	0.5667	0.4885
6	0.5879	0.3305	0.3805	0.5989
7	0.5909	0.7575	0.6132	0.5662
8	0.4486	0.2535	0.3958	0.595
9	0.6811	0.4532	1.0	0.7213
10	0.728	0.5966	0.9068	0.7102
11	0.8269	0.5353	0.9233	0.7911
12	0.8002	0.857	1.0	1.0
13	0.9601	0.3762	1.0	0.7216
14	0.6482	0.4903	0.7466	0.7245
15	0.8733	0.5791	1.0	0.7275
16	0.5171	0.4621	0.8147	0.6001
17	0.6476	0.6416	1.0	0.8335
18	0.6466	0.2132	0.5602	0.4135
19	0.9515	0.6502	0.7621	0.622
20	0.8452	0.6619	0.7673	0.615
21	0.8865	0.4576	0.7043	0.9008
22	1.0	0.5365	1	0.7802
23	0.8088	0.58	0.5446	0.5711
24	1.0	0.7589	0.6794	0.6827
25	0.5726	0.7212	0.7218	0.5477
26	0.7191	0.5363	0.6552	0.7233
27	0.6689	0.6039	0.7298	0.7708
28	0.9419	0.6086	0.7692	0.6635
29	0.7931	0.3985	0.8128	0.6728
30	1.0	0.7874	0.7894	0.64
31	0.8425	0.5138	0.8681	0.8508
32	0.9472	0.5094	0.8789	1.2949
33	0.8382	0.8416	0.886	0.7249
34	1.0	0.6018	1.0	1.0
35	0.841	1.0	0.7659	0.8543
36	0.8746	0.5177	1.0	0.6459
37	1.0	0.2918	1.0	0.6653
38	0.9064	0.5044	0.8168	0.7577
39	1.0	0.4806	0.6552	0.6132
40	1.0	0.5358	0.7729	0.6759
41	0.8734	0.4813	0.8872	1.0
AVERAGE	0.7905	0.5545	0.7742	0.7234

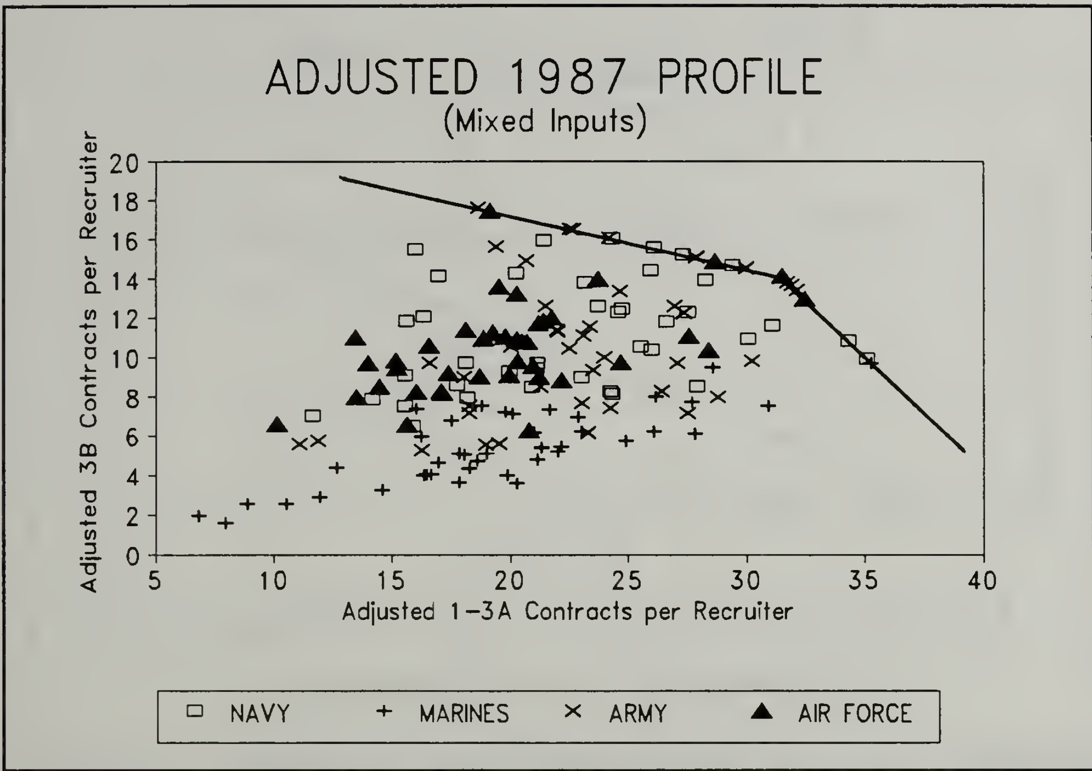

FIGURE 7: 1987 Adjusted Frontier

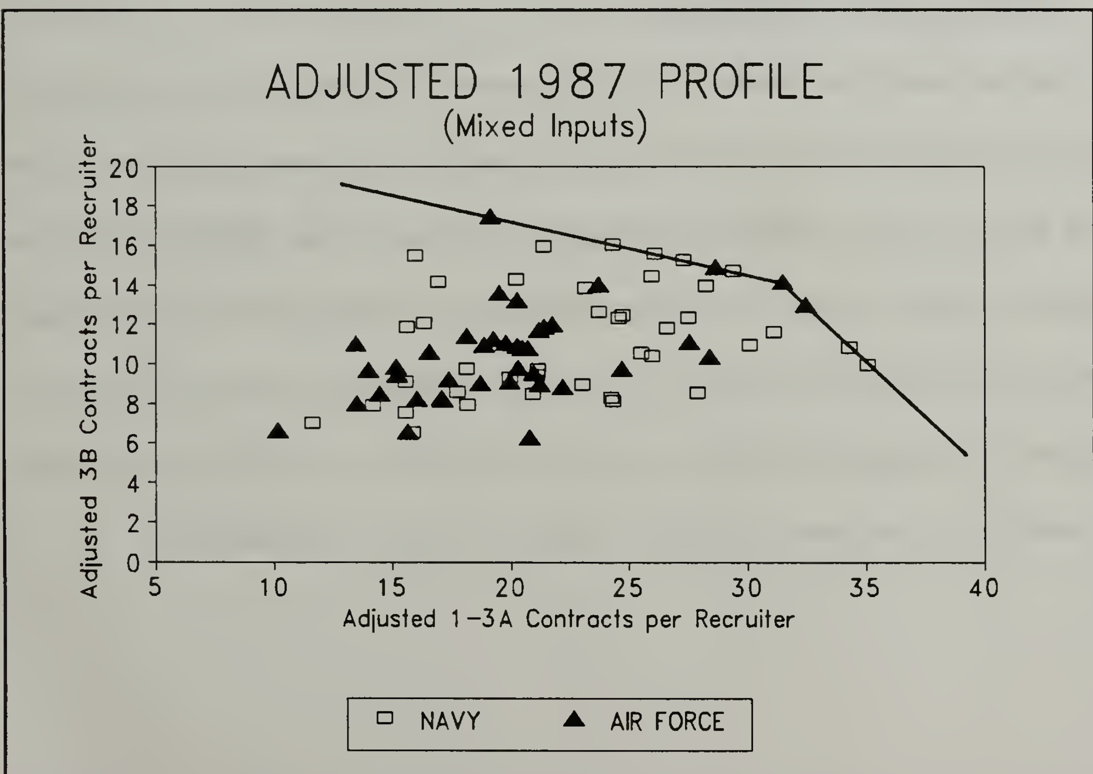

FIGURE 8: 1987 Adjusted Efficiency Frontier for Navy and Air Force Districts

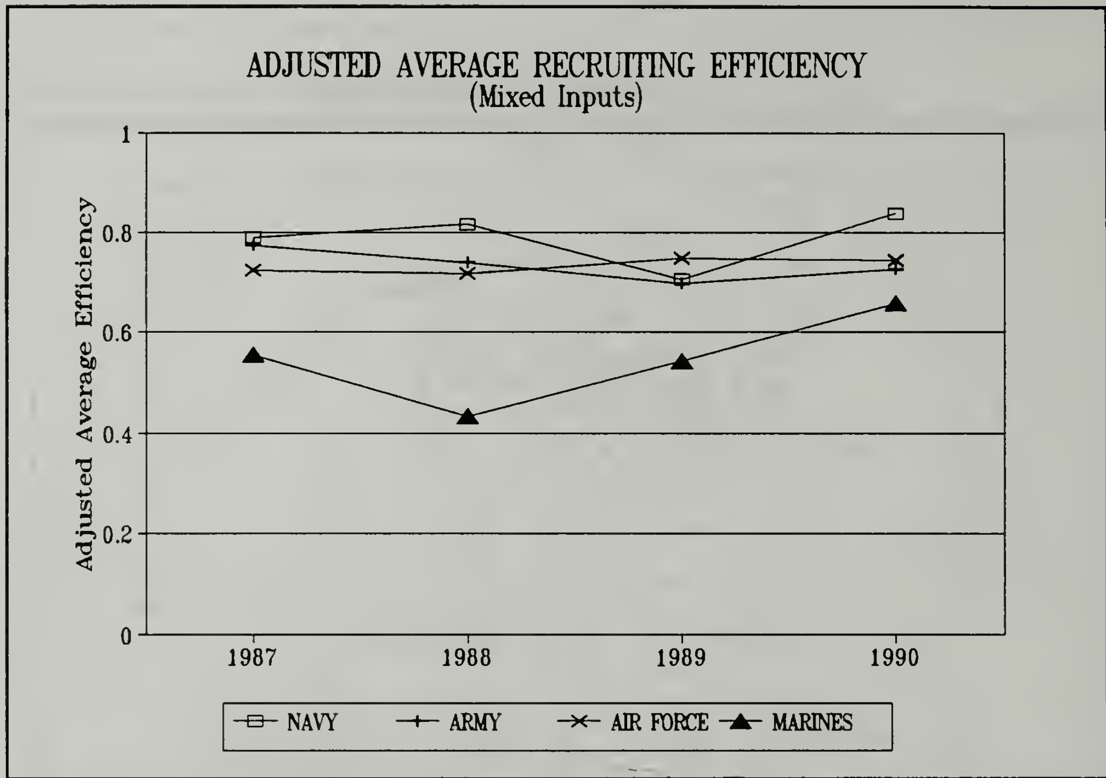

FIGURE 9: Average Recruiting Efficiency Based on DEA2

C. OTHER APPLICATIONS

Besides using the results from DEA models to identify the causes and/or methods to remedy inefficient districts, a graphical representation such as the one in Figure 10 also indicates recruiting practices of the different Services. This figure clearly points out that in 1990 Navy recruiting efforts were focused on Type 3B contracts, whereas the Air Force's efforts focused on Type 1-3A contracts. In trying to fill billets with the best recruits, the graph suggests that the Navy should consider shifting its efforts to Type 1-3A contracts.

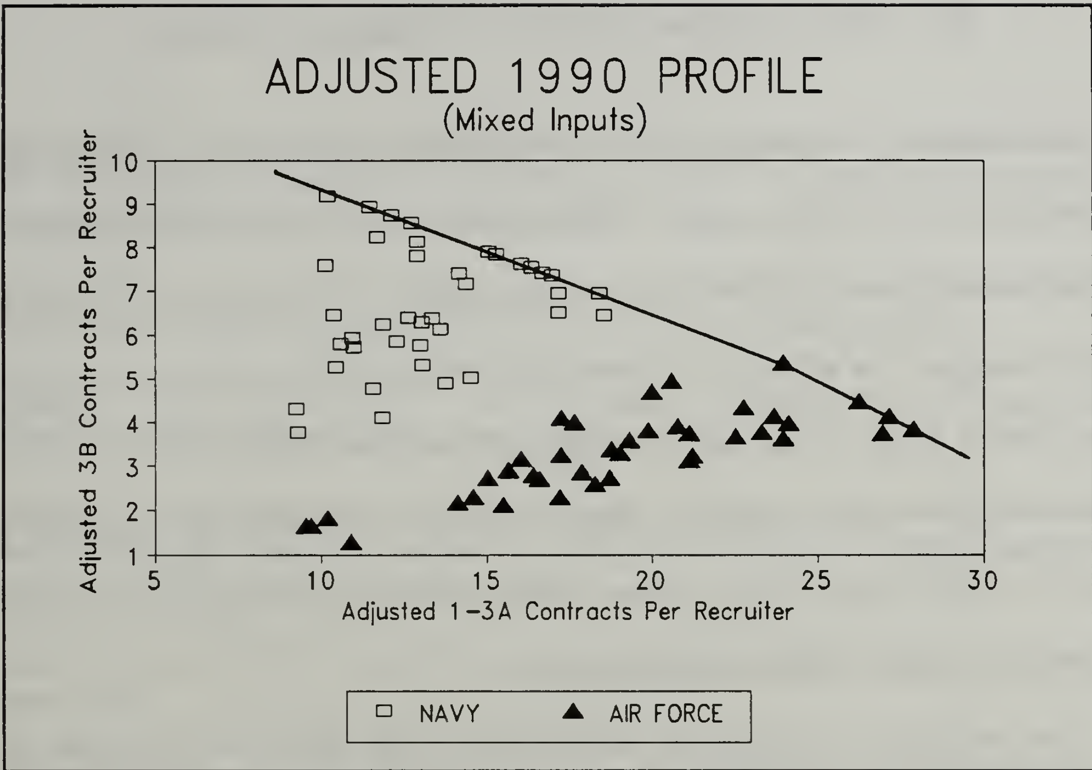

FIGURE 10: 1990 Adjusted Frontier for Navy and Air Force Districts

IV. CONCLUSION AND RECOMMENDATIONS

This thesis provides procedures for analyzing the efficiency of recruiting efforts based on two DEA models. One model treats all inputs as discretionary and the other does not. The two procedures were implemented in GAMS and used to analyze the efficiency of recruiting districts from the four services, Navy, Marine Corps, Army and Air Force, in the years 1987 to 1990. The two procedures gave two drastically different results. However, the procedure based on DEA2 was a more general model and may have provided a more accurate assessment of recruiting efficiency.

The results from this study also identify applications which should be further explored. Below is a list of a few applications:

1) The procedures described in this thesis can be used to analyze efficiency of zones and stations.

2) The levels of inputs and outputs from efficient districts, zones and stations can be used in the restructuring or realignment of the recruiting organization.

3) The efficiency ratings produced by the procedures can be used as a management tool, for inefficient units (districts, zones and stations) deserve management attention during budget downsizing.

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